

**FINAL REPORT
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**ROSSI X-RAY TIMING EXPLORER OBSERVATIONS OF THE
GAMMA-RAY BLAZAR PKS 2155-304**

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Final Report: RXTE Observations of PKS 2155-304

Introduction.

PKS 2155-304 is the archetypical X-ray-selected BL Lac object (XBL). It is one of the brightest BL Lacs at x-ray through optical wavelengths where it has a relatively featureless continuum and displays rapid, large amplitude variability. This continuum is thought to be direct synchrotron emission from a distribution of ultra-relativistic electrons which extends to unusually high energies (Edelson et al. 1995).

The gamma-ray emission from PKS 2155-304 constitutes a second, separate, spectral component. Observations with the EGRET telescope aboard the Compton Gamma Ray Observatory (CGRO) show that the spectral energy distribution of this gamma-ray component must peak at energies above 10 GeV (Vestrand et al. 1995). This, plus the realization that the extension of the synchrotron component into the x-ray band meant that ambient photons would be scattered to TeV energies, led to predictions that PKS 2155-304 would be a detectable TeV gamma ray source (Vestrand et al. 1995; Stecker et al. 1996).

The University of Durham group has recently reported the discovery of TeV gamma ray emission from PKS 2155-304 (Chadwick et al. 1998, 1999). The TeV emission was detected in 1996 September and 1997 October/November, with the largest fluxes being measured in 1997 November. During 1997 November, we detected a record high GeV gamma-ray flux from PKS 2155-304 with CGRO/EGRET (Sreekumar and Vestrand 1997) and subsequently very high x-ray fluxes were measured with BeppoSAX (Chiapeeti et al. 1997). Here we report on the record x-ray fluxes measured with the Rossi X-Ray Timing Explorer (RXTE) during the GeV/TeV outburst.

RXTE X-Ray Observations.

In November 1997, after our detection of an extremely high GeV gamma-ray flux from PKS 2155-304, we began a short series of target of opportunity observations with RXTE to determine the x-ray properties of the source during the gamma-ray flare. Specifically, we made Proportional Counter Array (PCA) and High Energy X-ray Timing Experiment (HEXTE) observations of nominal 2.5 ksec duration on 20, 21, and 22 November 1997. Our analysis of those data indicate that the x-ray flux on 20 and 21 November 1997 was $F(2 - 10 \text{ keV}) = 2.3 \times 10^{-10} \text{ erg cm}^{-2}\text{s}^{-1}$ and slightly dropped to $1.6 \times 10^{-10} \text{ erg cm}^{-2}\text{s}^{-1}$ by 17:00 UT on 22 November. The 20-21 November x-ray fluxes are the highest ever observed in the 2-10 keV band for PKS 2155-304.

The x-ray spectral shapes we measured during the 1997 November flare show downward curvature consistent with the idea that the synchrotron component is rolling off at keV energies. If we fix the column depth at the galactic value $n_H = 1.36 \times 10^{20} \text{ cm}^{-2}$ (Lockman and Savage 1995), then the 2.5-30.0 keV spectrum measured by the PCA on 20 November 1997 at 22:44-23:39 UT cannot be fit with a single power law. However, a good fit is obtained if we use a broken power law with a low energy photon index $\alpha_L = 2.51(\pm 0.08)$, a high-energy photon index $\alpha_H = 3.04(\pm 0.03)$, and a break energy $E_b = 4.01(\pm 0.22)$ keV. The 21 November measurements taken at 15:16-15:41 UT show a similar spectrum with $\alpha_L = 2.72(\pm 0.08)$, $\alpha_H = 3.06(\pm 0.04)$, and $E_b = 4.33(\pm 0.40)$ keV. While yielding a slightly lower flux, the 22 November measurements taken at 17:00-17:33 UT are also well fit by a broken power law but with parameters: $\alpha_H = 2.98(\pm 0.03)$, $\alpha_L = 2.20(+0.30/-1.41)$ and a break energy $E_b = 3.50(\pm 0.45)$ keV.

To act as control observations, we examined PCA measurements of PKS 2155-304 made when either the TeV or GeV gamma-ray fluxes were known to be low. During 30 December 1997-13 January 1998 we made follow-up EGRET observations of the GeV emission from PKS 2155-304 and marginally detected GeV flux at a level approximately a factor of four smaller than the November 1997 peak flux. Our simultaneous PCA observations on 9-11 January 1998 measured 2-10 keV fluxes that had decreased by a factor of seven from those observed on 20-21 November 1997. Unlike the November 1997 spectra, the 2.5-15.0 keV spectrum measured on 9 January 1998 at 2:59-3:40 UT can be acceptably fit ($\chi^2_\nu = 0.95$ for 32 d.o.f.) using the galactic column depth and a single power law having photon index $\alpha = 2.83(\pm 0.04)$. Chadwick et al. (1998) report detection of TeV flux from PKS 2155-304 in September 1996, however the TeV flux apparently decreased and they were unable to detect it in October or November 1996. While we do not have strictly simultaneous TeV and x-ray observations, the contemporaneous PCA observations made on 14 November 1996 show an x-ray flux which is a factor of five smaller than those observed during the November 1997 TeV gamma-ray flare. Our observations are therefore consistent with the pattern of correlated x-ray and gamma-ray flux outbursts observed in the two well-studied TeV emitting XBLs, Mrk 421 and Mrk 501.

Measurements taken with the All-Sky Monitor (ASM) aboard the RXTE satellite also suggest a correlation between elevated x-ray and gamma-ray emission. While substantially less sensitive than the PCA, the broad field of view of the ASM provides much better temporal coverage and is sensitive enough to detect major flaring activity from PKS 2155-304. Comparison of monthly ASM counting rates derived by averaging over days when TeV observations were made with 5 months of TeV gamma-ray monthly counting rates indicates a positive correlation. Our GeV gamma-ray measurements with EGRET suggest that the correlation between

gamma-ray and x-ray flux exists on an even shorter timescales. Subdivision of the November 1997 EGRET observations indicates that the bulk of the >100 MeV emission was detected during 11-14 November. While the statistics are poor, measurements by the ASM hint at a strong x-ray flare on 12-13 November simultaneous with the GeV flare and perhaps a second smaller flare on 19-20 November. Since the TeV gamma-ray and pointed x-ray observations did not begin until the 19th and 20th respectively, we suspect that they missed an even larger outburst on 12-13 November.

The available PKS 2155-304 data show a correlation between the 2-10 keV x-ray outbursts and GeV/TeV gamma-ray outbursts. We conclude, therefore, that monitoring x-ray emission can therefore provide an important trigger for gamma-ray studies of XBLs.

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